

Titan Aeroover All-Terrain Vehicle

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Abstract. A preliminary design for a Titan mobility system is a modified blimp that can operate in Titan's thick, cold atmosphere as well as drive on its solid surfaces and anticipated liquid hydrocarbon oceans. Testing with models has begun and technology focus areas have been identified as materials, control, navigation, deployment, and power.

BACKGROUND

The Jet Propulsion Laboratory (JPL) is presently evaluating various types of inflatable vehicles for operation at Saturn's largest moon, Titan, which is the only moon in our solar system with a significant atmosphere. The atmosphere is composed primarily of nitrogen and has a surface pressure of about 1.4 bars with a temperature of about 93 K (Lorenz, 1993). With a density of about four times that of Earth's surface atmosphere, Titan is ideal for ballooning. For any given balloon size, the payload carrying capacity is about four times greater at Titan than at Earth.

The surface winds on Titan have been estimated to be approximately 0.5 m/s, while upper level winds can be considerably higher. Saturn's orbit is about ten times further from the Sun than Earth's orbit, and thus the sunlight intensity reaching Titan's upper clouds (about 120-km altitude) is about 100 times less than that reaching Earth's upper clouds.

Furthermore, Titan's smog-like clouds are so obscuring that the amount of sunlight reaching Titan's surface is less than 1/1000th that at Earth's surface. The cold surface of Titan is believed to be composed of rock and water ice, as well as oceans of liquid methane-ethane (Lorenz, 1993).

POSSIBLE TITAN MISSION SCENARIO

The primary science mission goals for Titan exploration include:

- Determine what biotic chemistry may be taking place, and search for possible evidence of past or present life.
- Measure the composition, especially organics, in Titan's atmosphere and on its liquid and solid surfaces.
- Understand the geological and meteorological processes.

To obtain these science objectives, it is necessary to have full atmospheric mobility on Titan, as well as mobility capabilities on Titan's solid and liquid surfaces. One such means of mobility is a blimp-like vehicle with a lower flotation wheel that would allow additional solid and liquid surface mobility (Figure 1). This aerobot/rover, or Aeroover, would be capable of flying from sea level (1.4 bars, 93 K) to as high as 10-km altitude (0.8 bar, 82 K).

Higher altitudes are hazardous due to the possibility of methane ice formation above about 14-km altitude at middle latitudes and as low as 7.5 km at equator latitudes.

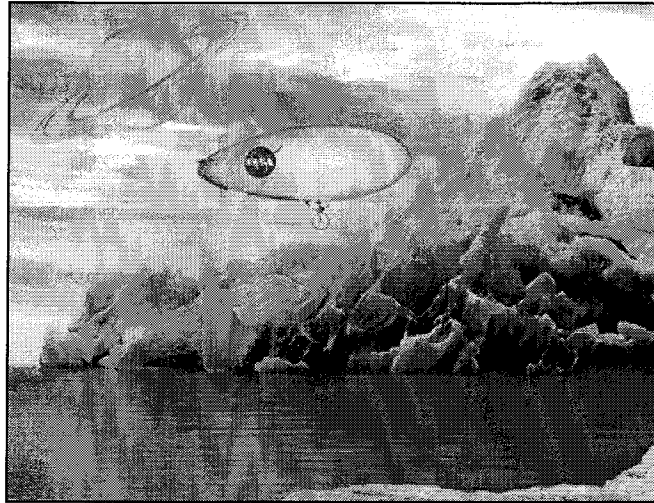


FIGURE 1. Titan Aeroover.

At 10-km altitude, however, the winds are strong enough to allow complete circumnavigation of the moon every one to two weeks. The Aeroover would essentially be “orbiting” Titan well below the upper obscure clouds and could, for the first time, allow detailed imaging of the moon, which appears only as an orange dish from space.

One possible mission scenario is shown in Figure 2. After entry into Titan’s atmosphere, a parachute would pull out a deflated blimp. While falling, the blimp would be filled with helium, or hydrogen, and would gently descend to the surface due to a slightly positive weight. The Aeroover could then reascend using propeller power or by heating the blimp cavity with waste heat from a radioisotope thermal generator (RTG). The blimp could make repeated descents to the surface through direct commands from Earth or by autonomously seeking certain targets, such as biosignatures or heat sources.

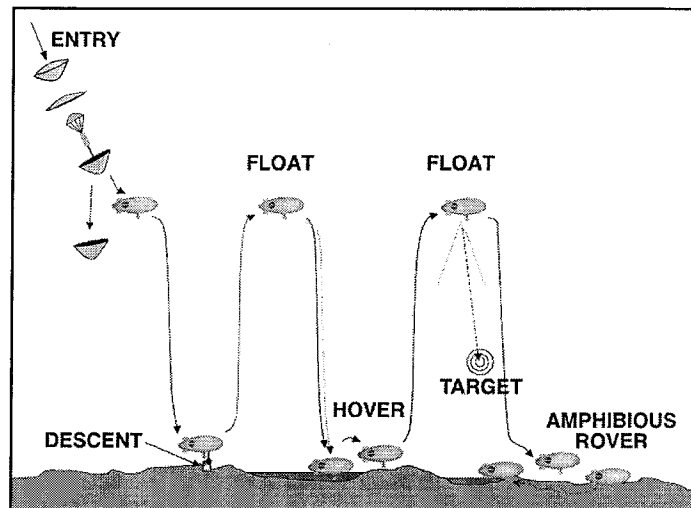


FIGURE 2. Mission Sequence.

PRELIMINARY AEROVER DESIGN

A preliminary schematic for a 200-kg Aeroover is shown in Figure 3. The Aeroover would be approximately 12 meters long by 2.5 meters maximum diameter. At sea level, the Aeroover could be a zero-pressure vehicle (internal pressure is the same as external pressure) while at 10-km altitude, the Aeroover would be super-pressure, (internal pressure slightly higher than ambient). Thus, at 10-km altitude, the blimp cross-section would be circular while at lower altitudes, the cross-section would be somewhat limp and would require plastic nose-battens to retain an aerodynamic shape. Alternatively, the blimp could retain an internal, ambient-filled bladder to remain always super-pressure, although this would require extra mechanism.

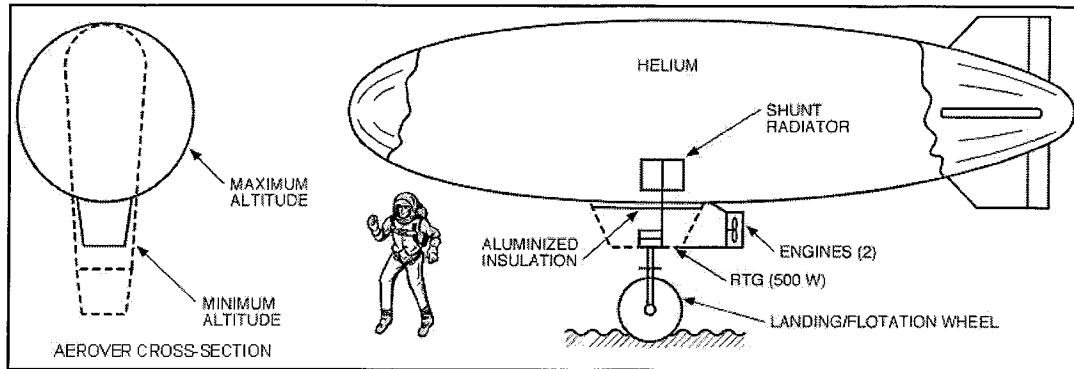


FIGURE 3. Titan Aeroover Schematics.

The Aeroover would have a large landing/flotation wheel located below its center of mass to allow mobility on both solid and liquid terrains. The gondola would contain most of the science instrumentation, communications, power (RTG), and both engines, which would be fully directional.

A controllable, variable conductance heat pipe would be attached to the surface of the RTG to allow up to 200 watts of RTG waste heat to be directed into the Aeroover's central cavity. This additional heating is enough to compensate for the vehicle's slightly positive weight, and allow the Aeroover to ascend to 10-km altitude without any engine power whatsoever.

At Titan's surface, the blimp would have a maximum speed of about 1.5 m/s, while consuming about 50 watts of power. The total power available from a 500-watt Alkali Metal to Thermal Electric Converter (AMTEC) is estimated to be about 100 watts (Mondt, 2001). The AMTEC RTG is preferred for this application due to its high efficiency and low mass, but it is still under development. If the technology is not available at the time of an Aeroover mission launch (≥ 2010), then conventional RTG power sources will be used.

PRELIMINARY AEROVER TESTING

Initial testing of Aeroover concepts has begun with materials research and scale-model Aeroover mobility tests. The first Aeroover model tested was a commercially available one-meter blimp that was modified to allow surface mobility (landing wheel added), operation as a partially deflated zero-pressure vehicle (plastic nose battens added), and heat-activated altitude control (black patch added to absorb external radiant heat). This blimp is shown in Figure 4, flying above an Inflatable Rover being developed for Mars (Jones, 1999). The model exhibited excellent control both in the air and on solid surfaces. Altitude variations were fully controllable by engine fan thrusts, by radiant heat input (ascent), and convective cooling (descent).

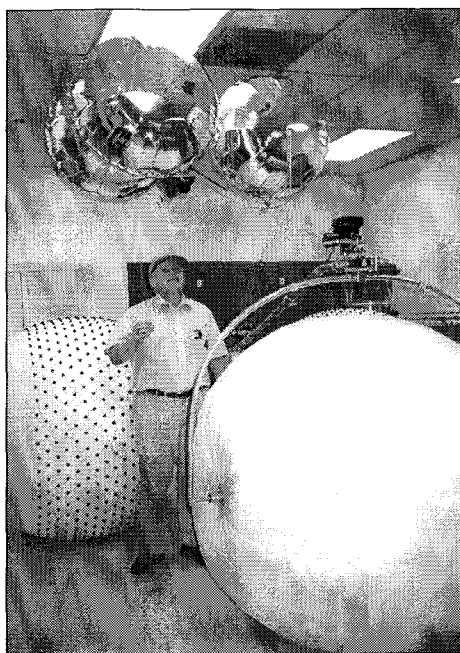


FIGURE 4. Three-Wheeled Early Titan Aeroover.

A larger, six-meter commercially available blimp has recently been purchased and is being modified for testing as a Titan Aeroover (Figure 5). A landing floatation wheel has been added that will allow testing on solid land as well as on liquid lakes. The engines are rotatable to allow powered ascent, and a section of the upper blimp body will be blackened to demonstrate zero-pressure heated ascent using solar heat, instead of RTG heat. All mobility test results will be compared with theory to ascertain accurate mobility and thermal models.

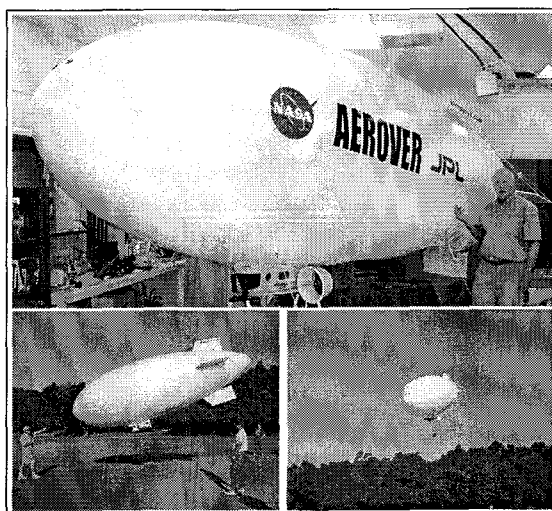


FIGURE 5. Titan Aeroover Tests.

An autonomous guidance system is presently being designed to allow the Aeroover to proceed to specified targets and return to an original operating point. Various science instruments will also be incorporated on the Aeroover's gondola to allow in-situ testing. One of the autonomous guidance systems to be tested is an optical guidance system to allow the blimp to autonomously seek sources of heat. If there are presently active volcanoes or geysers on Titan, they are likely to contain water and would thus be a prime candidate for bio-seeking instruments.

Another area of Aerover research presently being explored is that of the Aerover envelope material. Although there are many polymer materials that can function well at cryogenic temperatures (mylar, kapton, kevlar, PBO, etc.), it was previously unknown how to make a non-porous, strong, envelope whose gores could be sealed to survive Titan's 80-93 K temperatures. A recent breakthrough by Taconic Corporation, however, has demonstrated that a tough PBO fabric weave can be coated with teflon and aluminized to create a non-porous tough envelope with a relatively light aerial density of about 100 gm/m². Furthermore, the teflon can be sealed to itself by means of using a teflon precursor as glue (Yavrouian, 2001). A number of other material combinations are also being considered and tested.

CONCLUSIONS

The best mobility means to obtain all primary science objectives for a Titan atmosphere mission appears to be the use of a combination aerobot/rover or Aerover. This modified blimp would have full mobility in Titan's thick, cold, atmosphere as well as on its solid surfaces and anticipated liquid hydrocarbon seas. At least one possible blimp envelope material (teflon-coated PBO) has been identified, and other material combinations are being evaluated. Other technology areas that must be developed are control, navigation, deployment, and power.

ACKNOWLEDGMENTS

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